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ABSTRACT

In this paper, the fundamental characteristics and capabilities of ATM (Asynchronous Transfer Mode) networks in a distance learning environment are examined. Current and projected ATM applications are described, and issues and challenges associated with developing ATM networking solutions for instructional delivery are explored. Other topics include guidelines and strategies facilitating ATM implementation in the educational setting and costs of ATM products. (Author/AEF)

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Paper

A Managerial Analysis of ATM in Facilitating Distance Education

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Abstract

In this paper, the fundamental characteristics and capabilities of ATM (Asynchronous Transfer Mode) networks in a distance learning environment are examined. Current and projected ATM applications are described. Issues and challenges associated with developing ATM networking solutions for instructional delivery are explored. Guidelines facilitating ATM implementation in the educational setting for instructional enrichment are presented.

Introduction

ATM (Asynchronous Transfer Mode) is a connection-oriented, multiplexing and switching technology that is uniquely suited for the development and implementation of multi-service broadband networks. With its promise of universal connectivity and projected ability to seamlessly link faculty, students, and resource material at diverse locations in high quality educational environments, ATM is viewed as a key enabler for distance learning and networked multimedia and virtual reality applications.

Pilot networks such as BAGNet (Bay Area Gigabit Testbed Network) (*http://george.lbl.gov/BAGNet.html/*), BEATMAN (Boulder Area ATM Network)(*http://www.cs.colorado.edu/%7Ebatman/Home.html*), and ATDnet (Advanced

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Technology Demonstration Network) (*http://www.atd.net/atdnet.html*) are testing ATM operations in facilitating research initiatives that include telelearning and teletraining. CalREN (California Research and Education Network) participants including the University of California, San Jose State University, and San Francisco State University are exploring the use of ATM for videoconferences, teleseminars, teleconsultations, medical imaging, remote diagnostics, and statewide delivery of graduate programs in the field of library and information science (*http://www.pacbell.com/SuperHi/CalREN/Projects/*).

Although advances reflected in ATM technology create new opportunities for bringing leading edge applications to the desktop, the campus, and the wide area environment, debate continues in academic circles about whether the time is right to invest in ATM technology. An analysis of my case study research reveals various concerns among those investigating the feasibility of ATM implementation. Potential barriers include costs, functionality, absence of standards, and limitations on ATM's ability to integrate voice with other media. ATM technology is still in its infancy. Data and documentation on the effectiveness of ATM use in the educational domain are limited.

Questions that are integral to any consideration of ATM as a networking option for accommodating distance education include the following:

- What are the fundamental characteristics of ATM?
- How are institutions currently using ATM? What are some potential applications?
- What are advantages and limitations associated with ATM implementation?
- What areas of concern do educators have about ATM deployment?
- What are major ATM planning guidelines?
- Is ATM affordable?

This presentation addresses these questions, demonstrates the capabilities of ATM in the distance education environment, and presents strategies for ATM deployment.

Fundamental Characteristics of ATM

ATM is characterized by its high speed transmission efficiency in providing bandwidth-on-demand for multiple types of network traffic, and support for both private and public networks. ATM works at rates of 155-Mbps (OC-3) and 622-Mbps (OC-12) and is projected to reach 10-Gbps (OC-192). Optionally, ATM can also operate at 45-Mbps and lower rates.

At the core of ATM technology is a standard fixed sized 53-byte cell consisting of a 5-byte header and a 48-byte payload or information field. Since the cell length is constant and buffer memory size is always known for each cell, ATM-based networks switch information from source to destination very quickly. A multimedia application is made up of time dependent, continuous traffic such as video and audio and time independent traffic such as text. The ATM platform is designed to handle these elements equally well.

The terms "ATM," "cell switching," and "cell relay" are often used interchangeably. ATM has emerged as the technology of choice for next generation LANs (local area networks), MANs (metropolitan area networks) and WANs (wide area networks), and integrated networked environments.

Standards for ATM based integrated broadband networks are defined by the International Telecommunications Union-Telecommunications Sector (ITU-T), Internet Engineering Task Force (IETF), and the ATM Forum, an international consortium of vendors, governmental agencies, communications carriers, and end users. ATM can work over such physical media as copper and optical fiber and are being adapted to support wireless networks.

Applications

Distinguished by its projected capability for accommodating full motion video, audio, data, and images on the same network, ATM is designed as a universal transparent communications solution. With its capacity for supporting integrated services and real time-traffic requirements, ATM is expected to revolutionize instructional delivery to remote learners.

Operational since August, 1994, the North Carolina Information Highway (NCIH) is the first widescale public implementation of ATM technology (Patterson & Smith, 1994). According to Gary Munn (personal communication, June 8, 1995), Sales Engineering Manager with Fujitsu Network Switching, "the beauty about ATM use in the NCIH is its flexibility." Applications range from teleworkshops for physicians and medical students to virtual museum field trips offered by the North Carolina Museum of History so that students from outlying rural schools can participate in museum activities. In the metropolitan Wilmington area, a hospital serving as a node on the NCIH employs ATM by day for medical imaging and by night for delivery of advanced master's courses in nursing so individuals can upgrade skills and earn credentials on site without driving to the University of North Carolina at Chapel Hill.

Peggy Manring (personal communication, June 7, 1995), Head of the Distance Learning Department at the North Carolina School of Science and Math, indicated that videoconferencing is a popular NCIH option for delivering courses in history, psychology, and T'ai Chi to learners throughout the state. Manring noted: "Through handling full motion, real-time video, ATM facilitates the development of a collaborative learning atmosphere that resembles the ambiance found in a traditional classroom." NCIH is also designed to facilitate high speed connection to the Internet, thus allowing students to rapidly access large video and audio objects to further enhance the learning experience (*http://www.ncih.net/nciin/*).

NYNet is an ATM testbed in New York State providing high bandwidth connections for such institutions as Cornell University and Columbia University (*http://www.npac.syr.edu:80/users/hariri*). Projects in progress include development of approaches for incorporating virtual reality (VR) simulations into educational programs for students in kindergarten through 12th grades.

In Indiana, Ameritech introduced an ATM based network that will eventually connect approximately 1,700 schools to the Access Indiana Information Network (*http//www.ai.org/*) (Littman, 1996). This ATM network implementation will allow learners to virtually explore sites such as the zoo and art museum without incurring expense to the schools or disruption to the visited location.

In the field of telemedicine, ATM supports the transfer of MRIs and CAT scans between the Johns Hopkins University School of Medicine and the University of Maryland Medical Center. Neurosurgeons at the University of Virginia's Health Sciences Center use an ATM network configuration to consult with physicians at nearby health care facilities, thereby eliminating the need for patients or their doctors to commute between sites (Littman, 1996). LARG*net (London and Region Global Network), an ATM network linking the University of Western Ontario in Canada to three local teaching hospitals, enables health care training and research (*http://www.largnet.uwo.ca/*).

These examples of ATM in action are contributing to interest and enthusiasm in implementing telelearning applications. In a university setting, ATM paves the way for creating a technology mediated multimedia environment that can accommodate individual learning styles, skills, and competencies (Littman, 1995). ATM deployment can lead to telementoring, new instructional methods, teacher training, innovative models for courseware development and curricular delivery, and establishment of virtual classrooms across international boundaries. The learning experience in the classroom

can be enhanced by providing access to high resolution images, large quantities of data such as geographic maps, and multimedia resources from virtual electronic libraries.

Advantages and Drawbacks

Expanded communications requirements and the demand for multimedia applications have contributed to the popularity of ATM technology. ATM provides a seamless integrated environment that optimizes productivity and resource sharing. ATM technology can co-exist with existing networks and does not require replacement of equipment already in place. Designed as a multi-service platform, ATM also supports implementation of such fast packet communications options as frame relay and Switched Multimegabit Data Service (SMDS).

An ATM network can be as small as a desktop or large enough to span the globe. ATM is noted for its high speed, reliable performance, and ability to handle delay sensitive and bursty traffic. Expectations are that ATM will serve as the foundation for an integrated LAN-MAN-WAN infrastructure by the turn of the century.

Despite the promise of ATM, there are barriers to ATM deployment. These include costs for equipment, communications, and operations; expenditures required for making the transition to the new technology; and lack of off-the-shelf availability of services and products. ATM operations, protocols, network topologies, and application requirements are still being defined. The standards are not yet complete.

Bill Jones (personal communication, June 8, 1995), network analyst at Virginia Commonwealth University (VCU), indicated that a critical factor in ATM assessment is clearly understanding technical specifications of the products under consideration. Jones said: "You must determine how products function in terms of your computer communications requirements." Jones pointed out that ATM is a fairly new technology. "Some products won't work on single mode optical fiber while other products won't work at all. In investing in ATM, you must make sure the product is in actual use and not vaporware."

ATM switches provide the underlying physical structure for the network configuration. The ability of ATM switches to sustain end-to-end network performance contributes to the importance of this emerging technology. Yet, there can be inconsistencies in the operation and performance of similar switches from different vendors in network installations.

Vernon Williams (personal communication, June 14, 1995), lead systems engineer and network architect with communications and network services at VCU, stated: "A serious limitation associated with ATM is the lack of comprehensive standards and cross vendor support. At this point, you are virtually required to use a single vendor to supply all of your ATM equipment in order to achieve full functionality."

With its capacity for high speed transmission, ATM appears to be the ideal solution for multimedia applications. However, another drawback of ATM is its currently limited capacity for carrying voice traffic. Nolle (1995) noted that General DataComm (Middlebury, CT) and Newbridge Networks (Herndon, VA) are among ATM vendors trying to correct this limitation. However, standards for voice transmission via ATM switching are not expected to be adopted until 1997.

According to Munn (personal communication, June 8, 1995), with ATM's assurance of instant connections, users are under the false impression that ATM technology supporting instructional delivery and videoconferencing will be as easy to use as making a telephone call. Munn observed: "In reality, there is a steep learning curve."

ATM is in a state of transition. Factors that can contribute to user acceptance include consistency of physical interfaces, acceptance of agreed upon standards, lowered implementation costs, and quality of service guarantees.

ATM Deployment Concerns

Created to facilitate deployment of broadband communications networks, ATM is making the transition from theory and pilot tests to practical use. Despite ATM's potential for supporting instructional delivery, research, collaboration, and worldwide information exchange, an analysis of the discussions I have had with university leadership indicates that managers are reluctant to implement ATM fully until the technology becomes more mature and affordable.

The University of Minnesota Medical School links metropolitan hospitals over an ATM network to provide education to medical residents and deliver distance training to physicians in the field. Will Murray (personal communication, June 14, 1995), senior systems programmer with university networking services at the University of Minnesota, noted: "In terms of campus activities, we have had success in using ATM for pilot projects involving such high bandwidth implementations as 3-D molecular modeling. We will seriously look at ATM for our campus backbone network once the standards are more clearly defined and products are more readily available."

Steven Zink (personal communication, June 9, 1995), Associate Vice President for Information Resources and Technology at the University of Nevada, said: "In preparation for ATM, we have wired our campus with optical fiber. Although we plan to implement ATM, we don't want to be on the bleeding edge." Bill Bard (personal communication, September 1, 1995), telecommunications manager at the University of Texas at Austin, noted: "ATM poses technological uncertainties. We are presently using ATM for test purposes to discover if it works."

ATM usage also poses important pedagogical questions in relationship to distance education. What are the implications of ATM paradigms for the educational community? Should an ATM enabled virtual university replace a physical campus site? What are the merits and limitations of ATM implemented distance education sessions in comparison to traditional classes? What factors can contribute to effective teaching and learning in an ATM virtual classroom? Can ATM facilitated instruction accommodate diverse student and faculty abilities, motivations, and personalities? What re-orientation will be necessary for faculty who have resisted the use of electronic tools and techniques for either educational or personal reasons?

ATM technical issues are complex. The pedagogical questions associated with the educational use of ATM are multifaceted. In planning the migration to ATM, managers must ensure that expectations concerning ATM are realistic, promote understanding of ATM capabilities and applications, and address instructional concerns.

Planning Strategies

ATM is an emerging technology. The ATM infrastructure is intricate and detailed. How can managers develop ATM networking capabilities? What kinds of strategies can ensure that ATM contributes to effective educational outcomes? Is the cost/benefit relationship associated with ATM implementation strong enough to warrant a commitment of university funding? Does the technology satisfy institutional requirements?

Robert H. Evans (personal communication, June 12, 1995), Professor of Meteorology and Physical Oceanography at the University of Miami Rosensteil School of Marine and Atmospheric Science, is working on a pilot ATM project that involves the use of data from satellites to study ocean phenomena. Evans said: "A knowledgeable user can achieve fairly credible results with ATM, but ATM is clearly not a plug and play

environment." He added: "If I were a new user, I would definitely want to work with experienced individuals to ascertain the applicability of ATM and the present generation of software and hardware to the kinds of problems that I intend to solve."

In evaluating the suitability of ATM for the university environment, the need for ATM and its priority in relation to other computer communications requirements should be addressed initially. Applications selected for implementation should cost justify the expense of ATM investment.

Williams (personal communication, June 14, 1995) recommended a phased implementation. "At VCU, we are exploring the implementation of ATM supported multimedia classrooms at libraries on our medical campus and academic campus. Although ATM will play a key role in distance education, it will be pricey in the near term." Williams underscored the necessity of questioning vendors about the capabilities of their products. He noted: "It is important to be well versed in ATM technology and to compare services and offerings from several vendors. Don't stop your investigation after talking to the first vendor."

Questions that can aid in evaluating ATM viability include the following:

- What are the primary goals and objectives for an ATM implementation?
- What kinds of instructional applications can be enabled by ATM currently and in the future?
- What are the advantages and drawbacks of ATM in terms of present-day and long term technical and educational specifications?
- What expenditures are involved in a migration to ATM?
- How can ATM be integrated into the existing campus network infrastructure and facilitate distance learning?

A feasibility study can establish with greater accuracy the likely success of ATM deployment. Questions that can aid in conducting the feasibility study include the following:

- What are the total estimated costs for ATM implementation?
- Can ATM support existing and projected instructional applications?
- Can ATM contribute to the design of an effective learning environment?
- Are expectations concerning ATM educational benefits reasonable?
- Are university traffic requirements suitable for ATM deployment?
- What kinds of security mechanisms are available?
- Can ATM facilitate interoperability across diverse computing platforms?
- Are products from ATM vendors compatible?
- Are attitudes of key decision-makers positive toward ATM?
- Is there grassroots support for ATM?
- Is the time right for ATM deployment?

On the basis of the feasibility study, a decision can be made to implement ATM or discontinue the investigation. A report reflecting inputs from the feasibility study that can help in the decision-making process should highlight such factors as:

- Initial capital outlay
- Recurring expenses
- Resources required
- Anticipated educational applications and

- Benefits and limitations

The report should also feature an initial assessment of the projected ATM configuration in terms of criteria such as the following:

- Pricing
- Hardware and software features and capabilities
- Communication services
- Maintenance and operations requirements
- Adherence to standards
- Vendor and product reputation
- Training, instruction, and user support and
- Customer references

If the decision is made to proceed with ATM deployment, a request for proposal (RFP) can be developed for distribution to equipment vendors and communications carriers. Equipment vendors active in this field include Bay Networks (Santa Clara, CA), Cisco Systems (San Jose, CA), Digital Equipment Corp. (Maynard, MA), FORE Systems (Warrendale, PA), and 3Com Corp. (Santa Clara, CA). Communications carriers such as AT&T, GTE, Sprint, and MCI provide ATM services to educational institutions. RBOCs (Regional Bell Operating Companies) featuring ATM for universities include Bell Atlantic, BellSouth, NYNEX, Pacific Bell, Southwestern Bell, and US West. European network operators currently testing ATM technology across national boundaries include England's British Telecom, Germany's Deutsche Bundepost Telekom, and Spain's Compania Telefonica Nacional de Espana.

Another option for ATM implementation is outsourcing. Outsourcing involves contracting a vendor or communications carrier to build and deploy an ATM solution. For example, Ameritech configures and implements an ATM based network to accommodate institutional requirements. Ameritech also provides ATM equipment and communications services at a set lease fee, thereby eliminating the need to make a capital investment; monitors the installed ATM network, thus ensuring the integrity of information communications; and furnishes maintenance and support services.

Expenditures

The ATM market is in a state of flux. Costs for some ATM products that contribute to the development of an ATM configuration are decreasing, but the total outlay for an ATM network remains substantial. According to McQuillan (1995), prices for 25-Mbps ATM adapters and switch ports totaling under $1,000 are expected to sell at $500 in 1996. ATM NICs (Network Interface Cards) originally available at more than $4,000 in 1993 now sell for less than $1,000. There are, however, other economic factors.

Investing in ATM also involves expenditures for such essentials as cabling and switches. Jeffries (1995) noted that the price for ATM switches can range from $73,000 to $95,000. This figure does not reflect charges for such essentials as per-port price, ATM router interfaces, and equipment installation, maintenance, and support. Jeffries estimated that an ATM configuration can cost from $225,000 to $295,000. Steve Huber (personal communication, June 24, 1995), Manager of Advanced Technologies at Lockheed Martin Corporation, noted that the price of an ATM installation for a large company with four branch facilities nationwide is an estimated $245,000. Demand for ATM in a university environment will accelerate when this technology can bring real cost benefits and reliable performance to everyday network operations and specifications for ATM hardware and software are standardized and more clearly defined.

Tracking ATM

There is considerable excitement about ATM. Advances in this technology are occurring rapidly. Herman Hughes (personal communication, June 10, 1995), Professor of Computer Science at Michigan State University, predicts that an ATM infrastructure will be in place within the next three to five years. The projected full-scale implementation of ATM is generating a multiplicity of products and service providers and claims of hardware, software, and vendor superiority.

Jane Anne Hannigan (personal communication, May 20, 1995), Professor Emerita, Columbia University, advised: "Advances in this domain must be monitored so that we can develop reliable ATM solutions without being subjected to vendor pressures." Hannigan recommends creating an annotated file of information or "watching brief" that can be kept online. The Web is a rich source of ATM information. Technological developments are highlighted at such Web sites as *http://www.atm.forum.com/*.

Conclusion

ATM has emerged as an important technology for achieving an integrated networked environment. ATM can support innovative educational applications that reshape how future generations of students and instructors communicate, interact, and discover new knowledge domains.

Migration to ATM requires careful planning. Steve Huber (personal communication, March 15, 1995), observed: "The ATM field is changing rapidly. Those involved in the implementation process must be committed to continually modifying their strategies to reflect product and standard improvements without sacrificing the integrity of mission-critical goals and objectives."

By supporting reliable high speed, high performance transmission of multimedia applications to the desktop and in the wide area environment, ATM networks can lead to a revolution in teaching, learning, and research. An understanding of the capabilities, advantages, and drawbacks of ATM technology is critical in addressing challenges associated with the design and implementation of ATM networks for the distance education environment.

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